Structural priming and the representation of language

Structural priming and the representation of language

Holly P. Branigan

Martin J. Pickering

University of Edinburgh

Holly Branigan, Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh, EH8 9JZ, U.K. [corresponding author]

URL: http://www.psy.ed.ac.uk/people/view.php?name=holly-branigan

Email: Holly.Branigan@ed.ac.uk

Tel: +44 131 651 3187; Fax: +44 131 650 3461

Martin Pickering, Department of Psychology, University of Edinburgh, 7 George Square, Edinburgh, EH8 9JZ, U.K.

URL: http://www.psy.ed.ac.uk/people/view.php?name=martin-pickering

Email: Martin.Pickering@ed.ac.uk

Tel: +44 131 650 3447; Fax: +44 131 650 3461

Main text : 7,794 words ; Abstract + main text + references : 10,100 words

Abstract

Structural priming offers a powerful method for experimentally investigating the mental representation of linguistic structure. We clarify the nature of our proposal, justify the versatility of priming, consider alternative approaches, and discuss how our specific account can be extended to new questions as part of an interdisciplinary programme integrating linguistics and psychology as part of the cognitive sciences of language.

Key words: language production; linguistics; mental representation; psycholinguistics; semantics; structural priming; syntax

In our target article, we argue for an experimental approach to linguistic representation, and demonstrate how structural priming can be used to develop a psychologically motivated account of how people represent linguistic structure. If one utterance primes another, then we argue that they share structure. Patterns of priming are therefore informative about the way in which people represent language. While acknowledging the continuing value and importance of acceptability judgements in developing representational hypotheses, we proposed that priming is in many ways superior: It is an implicit behavioral measure that taps representation. And it allows us to study representation in all groups, including those such as young children who cannot make acceptability judgments.

In recent years, many experimental studies using structural priming have helped us to understand language users' representations. These studies suggest that semantic information is represented separately from syntactic information. The single semantic level encodes information about scope relations, information structure, and thematic structure. The single syntactic level, which draws on well-formedness constraints concerning local linear and hierarchical relations, includes syntactic category information and some 'missing' elements (i.e., elements that are not uttered) but does not involve syntactic movement. At present, linguists propose incompatible theories and there is no sign that the near-exclusive use of acceptability judgments is ever going to determine which type of theory is correct. In contrast, the findings from priming are compatible with some theories and incompatible with others.

The commentators take a unified view that researchers from different disciplines should cooperate in investigating linguistic representation, as a single integrated programme of research. They unanimously agree that an experimental approach to linguistic representation is valuable, and largely accept that structural priming is informative in this regard. In other

words, they do not feel that it is relevant only to the study of how language is produced and comprehended. But they differ about the versatility of priming, how directly it taps into representation, and its advantages over other methods (in particular acceptability judgments). They also take different views about our conclusions regarding aspects of linguistic representation, and make specific proposals for further research.

We are pleased that our proposal has met with such interest, and hope that it will encourage a future programme of cooperative interdisciplinary research on linguistic representation. In what follows, we have grouped our responses to their insightful comments under eleven headings.

R1. How can linguistic representation be investigated?

We begin by clarifying the nature of our proposal. Although commentators agree about the importance of experimental methods for investigating linguistic representation, some of them seem to assume that we advocate entirely renouncing the use of acceptability judgments. But as we make clear throughout the article, our argument is that researchers who are interested in linguistic representation should not be restricted to using *only* acceptability judgments. Specifically, we contend that 'the representations underlying language use need not be, and in fact should not be, investigated *only* via [acceptability] judgments' (Section 1.0). We further argue that '[our] goal is to consider alternative (experimental) methods to acceptability judgments that potentially address the linguistic representations that are implicated in language processing' (Section 1.1), that 'acceptability judgments are not *enough'*, and that 'researchers concerned with linguistic representations should not rely *solely* on such judgments, and should call on additional methodologies' (Section 1.2). Moreover we argue that 'acceptability judgments can be used (with appropriate controls) alongside structural

priming (and perhaps other experimental methods; see Section 1.3) as a means of developing representational hypotheses' (Section 1.4). (Emphasis added throughout.)

We therefore do not propose abandoning acceptability judgments as a linguistic method (**Adger; de Ruiter and de Ruiter; Hall, Mayberry, and Ferreira**). Nor do we argue that structural priming is the only tool that can be used to study linguistic representation (**Gonzalez-Marquez, Feist and Ströbel**; **Hartsuiker and Bernolet; Ziegler, Snedeker, and Wittenberg**). (We suspect that some commentators may have misinterpreted the phrase 'end the current reliance on acceptability judgments' in the abstract as an exhortation to 'end the current use of acceptability judgments'.)

But we do argue that priming has a privileged status – it is an implicit method that provides access to linguistic structure (i.e., strong generative capacity) and it is unaffected by an intervening theory "P". Acceptability judgments (whether obtained informally or formally) provide extensive and valuable, but suggestive, data (in the "context of discovery"; **Hagoort**). In this respect, they stand alongside the use of large-scale corpora to identify the types of utterances that occur and the contexts in which they occur (as **Lester, Du Bois, Gries and Moscoso del Prado Martin** note). Both of these methods provide evidence about the classes of acceptable sentences but need further assumptions to help determine linguistic structure – and here is where they encounter the problem of constituency tests. Other behavioral and neuroscientific methods (i.e., apart from priming) may provide evidence about linguistic structure without the need for constituency tests, but it is much harder to rule out explanations relating to the processing theory "P".

Adger argues that linguists use experimental tests of a theory "as an injunction to think about what the implications of the result mean". We agree that they should do this, but we do not believe that they typically do so (or else papers in theoretical linguistics would make far more

reference to experimental findings than they do). In sum, we wholeheartedly agree with **Hagoort** that there is no excuse for failing to use the available experimental and quantitative methods.

R2. How useful is priming?

A number of commentators express concerns about the versatility of structure priming in practice, and the extent to which structural priming studies are able to provide support for specific representational proposals (**de Ruiter and de Ruiter; Feldman and Milin; Francis; Hall et al.; Hartsuiker and Bernolet; MacDonald and Weiss; Mahowald, Futrell and Gibson; Maldonado, Spector, and Chemla; Martin, Huettig and Nieuwland; Meyer; Ziegler et al.; Rees and Bott).**

As **Mahowald et al. note,** the meta-analysis carried out by Mahowald et al. (2016) shows that structural priming is robust and highly replicable. Hence criticisms of other priming paradigms (e.g., in social psychology) (**MacDonald and Weiss)** are not relevant. The meta-analysis also highlights limitations in studies that compare the magnitude of priming under different circumstances. We stress that a large number of converging findings may be necessary to be able to be confident about theoretical claims.

With respect to our specific account, our claims concerning the monostratal nature of syntactic representation are based on many individual studies that together argue against some level of 'underlying' structure. Our intention in proposing the account in Section 2 is to encourage researchers to address both specific and general representational questions, in order to broaden the evidence base for theory development. Some of our specific claims may of course prove incorrect or incomplete in the light of further research.

Hence we acknowledge that there is need for reliable, replicable results, and that we need to be cautious about underpowered studies, interpreting null results, and so on (e.g., **de Ruiter and de Ruiter**; **Mahowald et al.; Maldonado et al.; Meyer; Rees and Bott; Ziegler et al.)**. These concerns apply to any scientific method. Clearly, priming studies require careful design, and some studies may be difficult to carry out in practice. But structural priming is not inherently more limited than other experimental (or non-experimental) approaches.

Other commentators are concerned that the value of priming is limited to cases involving pairs of roughly equivalent structures (e.g., **de Ruiter and de Ruiter; Meyer).** As we note, most current evidence comes from choices in language production, when a speaker can use one structure (e.g., passive) or another (e.g., active) to describe the same situation. In such cases, it is clearly necessary for alternatives to exist (and to be sufficiently frequent that in practice participants can be induced to produce both alternatives). But there are other methods of inducing priming, such as priming of alternatives that differ in meaning (Scheepers 2003), priming choices in comprehension (e.g., Branigan, Pickering, and McLean 2005), priming of eye movements during comprehension (e.g., Arai, van Gompel, and Scheepers 2007), priming response times in production ((Smith and Wheeldon 2001; Segaert, Wheeldon, and Hagoort 2016), priming response times in comprehension (Knoeferle 2014), or repetition suppression of the BOLD signal in fMRI adaptation (Segaert et al. 2012). These methods do not always require semantically similar alternatives, and they should allow us to use priming more extensively in the future.

A particular set of priming effects might appear compatible with more than one linguistic account (e.g., **Francis; Hartsuiker and Bernolet**). In some cases, there are ways to rule out one alternative (see R10 for some specific examples). In other cases, the data may fail to

distinguish between accounts – and this is why priming should be established as a general method in which conclusions are drawn from large numbers of studies considered together.

Some commentators raise concerns about the fact that priming effects reduce with increasing exposure (**Lester et al.; Ryskin and Brown-Schmidt**). Experimenters can take this into account (especially when small effect sizes are anticipated) through careful decisions about the size and composition of the stimulus set, testing adequate number of participants and items, or appropriate statistical analyses. **Ziegler et al.** observe that magnitudes of priming may vary across tasks. This simply means that just as for other experimental tasks (e.g., sentence recall versus picture description tasks), researchers should be careful about comparing results across tasks.

Finally, we do not share **Meyer's** pessimism concerning the relevance of priming for studying children and patients. For instance, priming studies have successfully addressed longstanding questions about the extent to which typically developing children and children with a Specific Language Impairment have abstract syntactic representations (Bencini and Valian 2008; Foltz et al. 2015; Garraffa, Coco, and Branigan 2015; Messenger, Branigan, and McLean 2011; Rowland et al. 2012).

R3. The directness of the relationship between grammar and processing

MacDonald and Weiss, Martin et al., and **Meyer** raise questions about the directness of the relationship between grammar and processing. Comprehension-to-production priming cannot simply be procedural as comprehension and production are different processes. Therefore we suggest it provides access to representation (as argued in Branigan, Pickering, and Cleland 2000). It could of course reflect a shared sub-process, for example accessing a linguistic constraint. But if this sub-process is the same across production and comprehension, it is

hard to see what it could reflect except for the representation itself. In fact, any form of structural priming (including production-to-production) is informative about linguistic representation, and researchers do not need to conduct comprehension-to-production priming studies to constrain linguistic theory. Note that a linguistic theory could treat the frequency of a syntactic constraint (e.g., V → V NP PP) as part of its linguistic representation (see **MacDonald and Weiss**) but our concern is with the representation of the constraints themselves rather than their frequency.

We do not claim that the apparent automaticity of priming is necessary for making claims about representation rather than processes. Instead, it suggests that priming is not affected by strategies or metalinguistic processes – concerns that may affect acceptability judgments. In other words, apparent automaticity gives us more confidence about linguistic representations.

R4. Does priming access all representations?

Some commentators suggest that priming may be insensitive to some linguistic representations (**Koring and Reuland; Maldonado et al.; Rees and Bott**). In other words, there may be levels of linguistic representation that are unaffected by priming. Some representations may be inaccessible to any method, whether because they have been compiled into different representations online (Berwick and Weinberg 1984) or because they have undergone attrition (see **Koostra and Rossi**). But the commentators are more concerned with the possibility that representations can be accessed but cannot be affected by prior exposure – a possibility that would somewhat reduce the effectiveness of priming. We propose that the use of a representation (whether in production or comprehension) will affect subsequent use of that representation; this is the logic that all accounts of priming depend on. But this is an assumption; if it is too strong, then priming would be somewhat less sensitive

than we assume. Such a limitation would not of course affect the conclusions that we can draw from (positive) demonstrations of priming.

Of course, failure to find priming does not demonstrate that it does not occur – a study may have been insensitive or underpowered. For example, priming without lexical repetition in comprehension has sometimes occurred (e.g., Pickering, McLean, and Branigan 2013; Thothathiri and Snedeker 2008) and sometimes has not (e.g., Branigan, Pickering, and McLean 2005; Traxler, Tooley, and Pickering 2014). Similarly, evidence for intonational priming is limited (**de Ruiter and de Ruiter**), but to demonstrate that intonational structure is represented (in roughly the form assumed by many linguists) and that it cannot be primed would involve extensive experimentation. It is too early to conclude that there is a level of linguistic representation that cannot be primed.

R5. What can acceptability judgments tell us?

Adger, Ambridge, Gaston, Huang and Phillips, Hall et al., and **Sprouse and Almeida** contend that we unfairly criticise a method that has been used fruitfully (and frugally) for decades – although other commentators (e.g., **Gonzalez-Marquez et al**.; **Lester et al.**) argue that we in fact over-emphasize its significance. We acknowledge that acceptability judgments have been a fertile method for generating hypotheses historically, and we do not advocate abandoning them. Indeed, their use is appropriate for field linguistics **(Hall et al.)** when identifying the possible sentences of a language and developing representational hypotheses (i.e., in the 'context of discovery'), but even in these situations researchers should carry out priming experiments when possible.

Our main concern with acceptability judgments does not lie with their informality (**Sprouse and Almeida**), though we do advocate avoiding informality where possible. We agree that careful experimentation can determine which judgments can be explained by processing

limitations (e.g., Sprouse, Wagers, and Phillips 2012). Presumably those judgments that cannot be explained by processing limitations are the judgments that are of interest to linguists, in the sense that they determine the set of sentences the grammar must be able to account for (i.e., its weak generative capacity). Sprouse and Almeida say that establishing these data is not in doubt and the concern is with what they call interpreting them. In other words, they argue that determining the set of sentences generated by the grammar is straightforward (i.e., the weak generative capacity) and that the difficult issue is identifying the structural representations that underlie those sentences (i.e., the strong generative capacity).

There may not be major concerns in practice about identifying the set of sentences that should be generated by the linguistic theory (though there remain concerns about consistency across types of speaker and task; Dabrowska 2010; Sprouse 2009). But acceptability judgments do not allow us to determine the underlying structural representations, as they cannot distinguish among competing analyses of the same data. In contrast, priming allows us to distinguish among such analyses – in Sprouse and Almeida's terms, to interpret the data. People may use representations that intrinsically include lexical content, or they may not. They may use representations that include elements that are not phonologically realised or they may not. The different representations proposed for DO sentences (e.g., a ternary-branching structure involving no "moved" elements versus a binary-branching structure involving "moved" elements; Pollard and Sag 1994 versus Larson 1988) are different interpretations of the same data. But they cannot both correspond to a speaker's mental representation for these sentences.

Some commentators defend constituency tests. For instance, **Gaston et al.** propose that the apparent contradictions that they yield can be resolved by further enquiry. This is not correct

– their contradictions are basic and widespread. For example, almost anything can be coordinated, so it would appear that almost anything can be a constituent. But this claim is possible only if we assume massively flexible constituency (Pickering and Barry 1993; Steedman, 2000) – a proposal contested by just about every other linguistic theory. And in practice linguistic theories disagree about the most fundamental points regarding structure (not merely the structure of ellipsis or *Wh*-questions). Our point is that traditional linguistic approaches assume that strong generative capacity can be determined by combining the sets of sentences compatible with acceptability judgments (i.e., weak generative capacity) with constituency tests. But if the tests are as flawed as they appear to be, this is impossible, even if Sprouse and Almeida are correct about the consistency of acceptability judgments.

In response to **Gaston et al.'s** query about the nature of structural priming, the example of lexical priming that we use to introduce priming as a phenomenon (Section 1.4) involves words that are related but not identical (i.e., associative/semantic priming). It may be more appropriate to compare structural priming with repetition priming of words (e.g., Scarborough, Cortese, and Scarborough 1977), which is long lasting, like structural priming (Bock and Griffin 2000). Structural priming appears to be relatively unaffected by contextual changes, for example between writing and speech (Cleland and Pickering 2006), but a more detailed exploration of such issues is necessary to fully understanding priming itself. Understanding a method is of course very important for drawing conclusions using that method, but priming (as a cognitive phenomenon) is far better understood than the complex combination of language processing, metalinguistic reflection, and decision-making that underlies acceptability judgments. Similarly, there is no well-grounded theoretical motivation for constituency tests (see Section 1.2).

R6. The stability of linguistic representations

Several commentators are concerned with the stability of the linguistic representations that are investigated in structural priming experiments **(Cai & Liu; Francis; Günther; Hall et al.; Kootstra and Rossi; Martin et al.; MacDonald and Weiss; Meyer; Ryskin and Brown-Schmidt; Ziegler et al.**). Some commentators suggest that their apparent instability, and the fact that priming itself can bring about representational changes, call into question the use of structural priming to investigate representation.

We agree that exposure to particular linguistic structures can affect speakers' linguistic representations, and any linguistic theory must be able to account for such effects. In practice, some researchers have argued that priming may offer an intervention to enhance foreign-language learning (McDonough and Mackey 2006) or recovery from aphasia (Cho-Reyes and Thompson 2012). More directly, Ivanova, Pickering, McLean, et al. (2012) found that participants occasionally produced a DO structure with a verb such as *donate* after encountering another DO sentence with *donate*, even though such sentences are usually regarded as unacceptable (**Ambridge**). In other words, priming can change the speaker's representation (at least temporarily). Other priming effects involve repeated exposure (e.g., developing the *needs* + *ed* construction; Kaschak and Glenberg 2004). Importantly, similar effects occur in studies in which participants repeatedly make acceptability judgments, thereby showing that such judgments are also affected by exposure (Luka and Barsalou 2005; Snyder 2000; though cf. Sprouse 2009).

So the method of investigation (priming) sometimes changes the phenomenon that it is investigating. But this observation is not problematic for our proposals. Our concern is with the nature of the representations that underlie language use at any given time – and such representations need not be static. Priming allows us to take a 'snapshot' of linguistic

representations. Moreover, we can track how those representations change across time and what causes them to change (e.g., **Cai and Liu; Kootstra and Rossi; Rowland and Monaghan).** For example, structural priming supports a developmental trajectory during L2 learning from item-specific representations in less proficient L2 speakers to abstract representations in more proficient L2 speakers (Bernolet, Hartsuiker, and Pickering 2013). Other studies have shown how children's syntactic representations at different ages do or do not differ from those of adults in specific ways, for example with respect to their independence from lexical or semantic content (Messenger et al. 2012; Rowland et al. 2012). Of course, we do not claim that they are the same in all respects (**Rowland and Monaghan**).

R7. Priming, individuals, and groups

Priming experiments are typically conducted over fairly large groups of participants, and some commentators (**Hall et al.; MacDonald and Weiss**) therefore assume that anything priming tells us must be at the group level – that is, holding over groups of participants with the same linguistic representations as each other. We do not make this assumption. We typically assume a common core of structural representations – that people who speak a particular language have similar linguistic representations. Of course, the acceptability judgment method also tends to make this assumption. But speakers of a language may have some different representations. Again, structural priming allows us to investigate variations across individual speakers (idiolectal variations) or populations (e.g., L1 versus L2 speakers of a language).

As with any other language, priming should be used to understand the representation of sign languages (**Hall et al.)**, and Hall, Ferreira, and Mayberry's (2015) paper paves the way for such research. L1 and L2 ASL signers may have differences in syntactic processing, but the priming data suggest that – as with L1 and (proficient) L2 speakers of spoken languages

(Schoonbaert, Hartsuiker, and Pickering 2007) – the syntactic representations they use during processing may have the same (relevant) characteristics. In these studies, syntactic priming does not tell us how these representations were constructed during processing (though see **Slevc and Ivanova** for relevant discussion), their interfaces with other representations, how those representations are instantiated in the brain, or how they developed.

Contra **MacDonald and Weiss's** contention, it is possible to study priming in individual participants. Such studies might require extensive data from an individual, just as in any single-case study. Moreover, if a structure can be variably represented within an individual, we can use priming to determine which representation is used more often (**Günther**).

Finally, **Francis's** observation that structural representations are not necessarily diachronically stable highlights how priming can address diachronic changes in structural representation (Pickering and Garrod, in press). Her example shows how priming could distinguish between competing theoretical proposals that acceptability judgments have not been able to discriminate, in the same way as priming has been used to examine historically-motivated accounts of lexical representation (Marslen-Wilson et al. 1994). In principle, corpus-based studies of structural priming (Gries 2005; Szmrecsanyi 2006) could also be used to track diachronic changes in structural representations.

R8. Structural priming and language processing (in monologue and dialogue)

A number of commentators discuss what priming may or may not tell us about language processing. Our focus in this paper is strictly on representation, and so we only consider processing to the extent that it is informative about representation (and hence we do not address questions such as the timecourse of priming [**Martin et al.**], or how priming may change people's parsing preferences [**Ryskin and Brown-Schmidt**]).

For example, **Slevc and Ivanova** point out that priming can reflect people's final parses but also their intermediate parses (e.g., Van Gompel et al., 2006). We therefore need to be careful about whether any priming effect depends on a temporary but abandoned representation rather than on the final representation. Investigations of abandoned analyses are of course also informative about the process of language comprehension (which analyses people consider, whether they hold on to abandoned analyses, and so on). But such issues are not directly relevant to linguistic representation.

Slevc and Ivanova also discuss how priming might interact with other aspects of cognition, such as depth of processing and working memory resources (see also **Hartsuiker and Bernolet; Martin et al**.). These issues may be important to an understanding of processing, for example with respect to the relationship between individual differences in priming and other aspects of cognition. Differences in method (and associated processing demands) can also affect priming magnitudes (e.g., Mahowald et al. 2016; **Ziegler et al.**), so care must be taken when comparing studies. But if such factors are controlled within an experiment, they do not undermine the informativeness of priming for understanding linguistic representation, as Slevc and Ivanova acknowledge.

We agree with **Kootstra and Rossi** that naturalistic studies of priming are beneficial, but for current purposes (i.e., linguistic representation) it does not matter whether any effects occur under laboratory conditions or not. We are fascinated by the priming of code-switching, but this programme of research is primarily relevant to processing (i.e., language selection) – assuming, of course that the code-switcher selects between two independent representations of different languages. In sum, priming is versatile and its implications go well beyond linguistic representation (see Pickering & Ferreira, 2008).

MacDonald and Weiss argue that priming may reflect a general (non-linguistic) tendency to repeat prior actions, as demonstrated by parallel priming effects in motor actions and syntax (Allen et al. 2010) and between domains such as music and language (van der Cavey and Hartsuiker 2016) (see also **Kempson and Gregoromichelaki**). But if priming occurs between language and non-language, it does not prevent researchers using priming to discriminate linguistic theories; it is just that some representations are shared with other domains. To take a more formal example, Steedman (2002) presented an account of action based on principles (functional composition and type raising) that are also used in Combinatorial Categorial Grammar (Steedman 2000). Extending these principles to action in general does not invalidate his account of linguistic representation – it just means that the same principles are used in quite different domains.

R9. Alternative approaches to linguistic representation

Alongside structural priming, some commentators suggest further methods for studying linguistic representation. **Ziegler et al.** argue that priming is not special. If any method appears to relate to linguistic representation (e.g., multi-voxel pattern analysis relating to thematic roles), then they assume that it can be used to constrain linguistic theory. This is reasonable in principle, but is in practice likely to always face the problem that any effect could be due to the "parsing procedure P". For example, it might appear that the N400 in ERP research could be diagnostic of semantic anomaly and hence semantic representation, whereas the P600 could be diagnostic of syntactic anomaly and hence syntactic representation. Whether an anomalous utterance in an ERP experiment produced a N400 or a P600 would then be informative about linguistic representation (e.g., Osterhout and Mobley, 1995, on anaphora). But it turned out that some semantically anomalous utterances produced a P600 (e.g., Kim and Osterhout 2005). This means that these ERP components are not

directly informative about linguistic representation. Rather than focus on one method, researchers might be able to combine findings from diverse methods and draw general conclusions about linguistic representation. But there is little sign of this happening, presumably because theoretical linguistics would ascribe any such findings to "P". Priming does not face this concern, in part because there is no need for an indirect intervening theory, but also because it has an established methodology that is largely consistently applied across studies (a property that it shares with acceptability judgments, of course).

We agree with **Rowland and Monaghan** that multiple methods, including corpus research and novel word studies, are desirable in developmental research. But such methods have important limitations for studying representation. It is unclear whether novel word studies, for example, are informative about underlying representations or about processing. We cannot tell whether children's reluctance to produce DO structures with novel verbs that they have previously encountered in PO structures is because they do not have an abstract (generalized) DO representation, or because they find it difficult to produce unusual word orders. In contrast, priming between DO sentences involving different verbs supports an abstract DO representation underlying these sentences (Rowland et al. 2012). As we note in R6, priming studies can address how representations change (e.g., whether a structure is lexically specific at time 1 but not at time 2).

With respect to non-experimental methods, **Gonzales-Marquez et al., Lester et al., and Rowland and Monaghan** emphasize the potential offered by corpus and distributional analyses for both developmental and adult research (see also **Rees and Bott**). These approaches offer valuable data about weak generative capacity and factors that may influence structural choices in language use (e.g., Bresnan et al. 2007) (see also R10 below). Recent advances in statistical analysis help researchers to exclude confounding variables. However,

straightforward distributional analyses are less informative than the substantial corpus-based evidence of structural priming (see Gries and Kootstra 2017) – an approach that that may also address some of the concerns about statistical power highlighted in R2 above. Moreover, experimental and corpus-based evidence for priming complement each other. (Note that **Kempson and Gregoromichelaki** and **De Ruiter and De Ruiter** query whether syntactic priming occurs in conversation on the basis of Healey, Purver, and Howes's, 2014, negative results. But their conclusions contrast with many other demonstrations of priming in conversation; e.g., Gries 2005; Gries 2011; Reitter and Moore 2014; Szmrecsanyi 2006).

Hagoort, Martin et al., and **Ziegler et al.** propose that neuroimaging techniques can address many representational questions. As **Hagoort** notes, fMRI adaptation (based on variations in the BOLD response dependent on previous experience) is a form of priming, and supports the segregation of semantic, syntactic, and lexical processing in ways that are shared across comprehension and production (Menenti et al. 2011; Segaert et al. 2012). But neuroimaging research not based on priming has so far been less informative about representation.

Cai and Liu suggest that although priming offers deeper insights than intuition-based data into the microscopic aspect of linguistic representation, it is less well suited to evaluating the macroscopic characteristics of language systems, and specifically the interconnectivity of elements at each level. Complex network approaches may offer an interesting way to study system-level representational similarities (e.g., between native and non-native speakers) and changes in these systems (e.g., during L2 learning), in a way that can complement the insights from structural priming into the development of linguistic representations in particular populations (such as L2 learners), or in principle in individual speakers.

R10. Details of our theory

Our linguistic account assumes an architecture that distinguishes distinct semantic, syntactic and phonological representations. We agree with **Hagoort** that it is largely compatible with the Memory Unification and Control model (Hagoort 2014; Hagoort and Indefrey 2014), a neurobiological model of language based on data from imaging studies that identifies discrete neuronal network contributions for unifying semantic, syntactic, and phonological information. However, various commentators dispute specific aspects of our account.

We acknowledge **Ziegler et al**.'s point that there is less structural priming evidence relating to semantic structure than to syntactic structure, a point that reflects the greater interest historically in the latter than the former (e.g., Bock 1986). But it is not contentious that structural priming of semantic structure occurs and that it is informative for theories of semantic representation (**Maldonado et al.**; see also Bunger, Papafragou, and Trueswell 2013, for priming of event structure, and **Rees and Bott** for extension to pragmatic representation). Furthermore, studies converge in supporting a lexically independent level of semantic representation that includes quantificational information. We anticipate that the growing interest in the use of structural priming to investigate semantic representation will give rise to more detailed theoretical proposals based on converging evidence from multiple studies, as has occurred for syntactic representation.

Ambridge, Gonzalez-Marquez et al., Günther, Lester et al., and **Ziegler et al.** express some scepticism about a level of syntactic representation that is independent of semantic and lexical information. The finding that priming of syntactic structure is not enhanced when thematic mappings or semantic features are repeated (Bock and Loebell 1990; Huang et al. 2016; Messenger et al. 2012) suggests that semantic information is not incorporated into syntactic structure. It specifically fits badly with the construction-based approach advocated

by **Günther**, who suggests that priming effects might hold between entire constructions (which could be related but of different types), or just their syntactic (i.e., form) or their semantic (i.e., meaning) components. The straightforward interpretation of a construction grammar is that it involves form-meaning pairings and that these pairings can be primed. This is compatible with integrated syntax and semantics. **Günther** suggests that priming can occur between the form or the meaning side of a form-meaning pairing. But if so, this means there is autonomy of syntax. Such autonomy can explain priming between sentences with the same syntax but very different meanings (e.g., from locatives to passives; Bock and Loebell 1990).

In our account, thematic relations and other semantic information are represented separately from syntactic structure, and are mapped to syntactic representations (e.g., Chang, Bock, and Goldberg 2003; Köhne, Pickering, and Branigan 2014; Cai, Pickering, and Branigan 2012). Not surprisingly, some mappings are preferred over others (e.g., Bresnan et al., 2007; Ferreira 1994; Kempen and Harbusch 2004). But such preferences do not imply that semantic (or indeed lexical) content is part of the syntactic representation. Moreover, acceptability judgments for sentences reflect their likelihood of occurrence (Bresnan 2007), so it is unsurprising that sentences involving preferred mappings are rated as more acceptable than sentences involving less preferred mappings (**Ambridge**). In fact, Ambridge's results suggest that acceptability judgments are affected by semantic factors, a point that reinforces our conclusion that acceptability judgments do not straightforwardly reflect syntactic representation.

With respect to the relationship between lexical content and syntactic structure, **Ziegler et al.** argue that function words can be a locus of priming, based on Ferreira's (2003) study. In fact, Ferreira argued for an autonomous, lexically independent syntactic component, consistent with our account: Participants did not produce structures that included complementizer *that*

following primes that included complementizer *that* unless the primes also involved the same syntactic structure. In other words, repetition of the function word alone did not determine choice of structure (see also Bock 1989).

Similarly, our claim that syntactic representations are independent of closed class features is not undermined by **Feldman and Milin**'s finding of differences in priming of single word production (measured by response latencies) depending on the modality of the prime (drawing vs. word), and differences in the specific verb form that was produced. Any such effects do not appear to relate to structural priming (as far as is known; Pickering and Branigan 1998).

Regarding open-class lexical content, priming evidence provides no support for redundant representations in which the same utterance (or part of an utterance) is represented both as a single lexicalized chunk and as the integration of several more schematic constructions **(Günther)**. If this were the case, we might expect stronger priming from frequently encountered phrases (which should be more likely to be redundantly represented), as there would be two potential sources of priming (Rowland et al. 2012). However Konopka and Bock (2009) found that idiomatic expressions and non-idiomatic expressions yielded the same priming.

Hartsuiker and Bernolet suggest that the lexical boost to priming (which appears to be short-lived) need not reflect a link between syntactic representations and the lexicon, but may instead arise from an explicit memory of the prime that rapidly decays, with the verb acting as a retrieval cue. Malhotra et al. (2008) demonstrated (using a dynamical systems model) that our assumption of a link between syntactic representations and the lexicon is compatible with a short-lived lexical boost. The longevity of the lexical boost does not therefore discriminate between our account and alternative accounts. Furthermore, it does not matter

whether explicit memory processes are involved in priming: Any such memories must still make reference to abstract structure (e.g., that the verb *give* appeared with an NP and an NP) to be able to explain priming between non-identical sentences (Branigan and McLean 2016). Note also that these memories cannot be based on specific wordforms (because the lexical boost is unaffected by repetition of specific features such as tense, aspect and number; Pickering and Branigan 1998).

Other commentators discuss alternative ways of conceptualizing an abstract level of syntactic representation. **Hudson** supports our overall approach but suggests that priming evidence suggests that we should abandon the standard assumption that constituent-structure is basic, and with dependencies (e.g., subject-verb agreement) being defined with respect to constituent-structure. Instead, he treats dependency as basic and constituency as derivative at best. It seems most straightforward to us to define priming (e.g., of Prepositional Object vs. Double Object) in constituent-structure terms (e.g., priming VP → V NP PP rather than V → V NP NP), but it would presumably also be possible to define it in terms of dependencies, for instance from V to N (i.e., the head noun of the NP) and V to P (i.e., the head preposition of the PP) rather than dependencies from V to N and V to N. Of course, priming of subject-verb agreement itself (Haskell, Thornton, and MacDonald 2010) fits particularly well with a dependency-based analysis. An analysis of priming in terms of a dependency-based grammar such as Word Grammar (Hudson 2010) would be very interesting.

Kempson and Gregoromichelaki propose that our data do not need to be interpreted in terms of hierarchical representations such as those derived from context-free constraints (or similar), and interpret it in terms of sequential patterns of processing actions (see also **O'Grady**). If those patterns discriminate between linguistic structures that prime differently (e.g., the sequential pattern for POs differs from the pattern for DOs), then their approach

may be able to capture priming data, and an analysis in terms of dynamic syntax would also be very interesting (Cann, Kempson, and Marten 2005).

Adger and **Koring and Reuland** (see also **Gaston et al.**) challenge our use of priming between unergatives and unaccusatives to propose that they have similar syntactic representations. In contrast, their favored accounts assume that unaccusatives have a very different structure from unergatives – a difference that would almost certainly preclude priming, given the sensitivity of priming to comparable syntactic differences (e.g., priming does not occur between constructions with different numbers of arguments). **Koring and Reuland** simply assume an analysis involving "NP-movement" but we query the assumptions that underlie analyses such as theirs. We do not dispute syntactic distinctions between types of subjects (though at least some relevant distinctions between unergatives versus unaccusatives may be semantic rather than syntactic; e.g., Zaenen 1988), but argue that these distinctions do not require different constituent-structure representations. Similarly, **Adger** assumes that a distinction between *Lily froze solid* and **Lily danced tired* means that *Lily froze* and *Lily danced* must have different constituent structures. Instead, it shows that *danced* and *froze* have syntactic properties that allow them both to combine with just a subject but which have different effects on combination with a subject and another constituent. We cannot conclude that *Lily froze* and *Lily danced* have different constituent structures. Approaches such as Koring and Reuland's and Adger's would lead to extremely complex constituent-structures and is challenged by theories assuming "flat" structures (e.g., Culicover and Jackendoff 2005; Pollard and Sag 1994).

Our concern with many other experimental methods is that their results can be due to processing (i.e., processing theory 'P' in Chomsky 1981). We therefore did not review all results (indeed we did not have the space to do so). As an example, Bever and Sanz 's (1997) finding of faster responses to a probe word associated with a subject noun that preceded an

unaccusative compared to an unergative verb could be due to semantic differences between unaccusatives and unergatives (rather than reactivating an antecedent at an NP-trace) (see also Agnew et al. 2014). Both **Koring and Reuland** and **Adger** point to many experimental studies that contrast unaccusative and unergative sentences, but none of them demonstrate that the distinctions are due to constituent structure differences. Many experimental methods such as studies using reactivation or visual world paradigms provide results relating to interpretation – there may be an underlying syntactic cause of the effects or there may not, but we typically cannot tell. In contrast, priming is informative about syntactic representation.

We also note that our description of "mainstream GG" (**Koring and Reuland)** is our best attempt to capture the key issues of a family of views and to ignore factional distinctions. It is not helpful to argue that we are using concepts that are obsolete within the authors' favored branch of linguistic theory – we are simply trying to describe a complex state of affairs and identify the core issues that we wish to dispute.

Kwon and Lee argue that priming evidence provides only limited benefit compared with acceptability judgments. But criticising a new method on the grounds that it has not discovered as much as an old method would simply lead to stagnation. Their specific point about distinguishing linear and hierarchical relations is more insightful. We believe that priming data support a single level of structure that is specified for linear and hierarchical relations together, rather than one in which hierarchical structure is independently represented. For example, Bernolet, Hartsuiker, and Pickering (2007) found priming between German and Dutch noun phrases which both have adjective-verb order (*the X that red is*) but not between English and Dutch, presumably because English has verb-adjective order. In other words, the priming is not localized at an unordered hierarchical level (relative clause, unspecified for order) and therefore we propose that such an unordered level does not exist.

In response to **Hartsuiker and Bernolet**, the absence of priming for PO structures following 'shifted' PO prime sentences is compatible with an account in which there is no priming of independent hierarchical relations, and thematic-function and thematic-order priming effects counteract each other (Cai, Pickering, and Branigan 2012).

We of course do not assume that syntax can be reduced to simple sequential structure (see also **Gaston et al.**) – otherwise we would not assume constituent-structure representations such as those in Fig 1. And priming also cannot be reduced to linear order. For example, it occurs when the internal structure of prime and target constituents are different (e.g., complex vs. simple noun phrases in dative priming; see Fox Tree and Meijer 1999; Pickering and Branigan 1998), or when the critical alternation occurs at a different location in the prime and target, for example datives in main versus subordinate clauses (Branigan et al. 2006) or noun phrases sentence-initially versus -finally (Melinger and Cleland 2011).

Hartsuiker and Bernolet and **Francis** question how we interpret the representation of coerced sentences. **Hartsuiker and Bernolet** argue that the control (event) sentences could be given a coerced reading (i.e., both sentences could have a missing predicate represented). But the picture presented with the prime sentence forced it to have an event reading. Additionally, although coerced and control sentences did not differentially prime the production of full VP targets (relative to VP-primes such as *began drinking the champagne*), they did differentially prime the production of coerced targets, with coerced primes inducing more coerced targets than control primes. This finding further suggests that participants did not postulate a predicate for control primes. **Francis** proposes that Raffray et al.'s (2014) data might be due entirely to syntactic priming and so might indicate that the three sentence types (*began the speech, began the champagne, began drinking the champagne*) all have different syntactic structures. The problem with this explanation is that a purely syntactic

account might argue that *began the champagne* had a covert V (corresponding to drinking) but *began the speech* could not have a covert V – and if this is the case, *began the champagne* should behave more similarly than *began the speech* to *began drinking the champagne*, contrary to Raffray et al.'s findings.

R11. Further directions

We argue in the target article that structural priming can be used to address outstanding linguistic controversies, and highlight some specific examples (Section 3.1). Commentators identify interesting further cases that exemplify the potential of this method.

Francis discusses how priming might be used to clarify the syntactic representation of quantificational NPs, and specifically whether they have the same representation as collective NPs. Assuming that an appropriate experiment can be designed (e.g., an alternative form for *a lot of papers*), then any finding that *A bundle of sticks* primes *A lot of papers* would suggest that quantificational NPs and collective NPs involve the same syntactic representation, in which the first noun acts as the head. We suspect that such priming would occur, because priming appears to be sensitive to categorical distinctions rather than featural distinctions (e.g., tense or number; Pickering and Branigan 1998).

O'Grady highlights how priming could be used to test specific representational questions across typologically diverse languages. As we note in Section 3.2, such studies can address fundamental questions about the diversity of linguistic representations and potential language universals. With respect to subject-verb sequences, it may well be possible to prime *neither is* versus *are* (for example) and demonstrate that such priming constitutes priming of subject-verb agreement, rather than simply priming of the verb form (see Haskell, Thornton, and MacDonald 2010). Any such priming could be due to semantic rather than syntactic relations, as both types of dependency affect choice of verb form (cf. Bock, Nicol, and

Cutting 1999). And even if the effects are syntactic, they could relate to a unit consisting of the whole sentence rather than one consisting of the subject and verb. For example, the locus of priming for *neither are satisfactory* could be NP_{+pl} V_{+pl} AP rather than NP_{+pl} V_{+pl}. We also suggest that priming different interpretations of *Everyone didn't finish the project* takes place at the semantic rather than syntactic level.

Rees and Bott point to Bott and Chemla's (2016) finding that scalar implicatures can be primed (see also **Maldonado et al**.). We see this as a fascinating example of how priming can be extended to further linguistic domains, specifically diverse aspects of structure relating to interpretation. Priming of pragmatic representations is of course compatible with it being sensitive to all levels of linguistic representation.

Cai and Liu and **Kootstra and Rossi** suggest ways in which structural priming can be used to investigate bilingual representation. In particular, **Kootstra and Rossi** note that priming can be used to study first language attrition. We agree – it could be used to determine whether an L1 had become completely inaccessible or not. It would of course be possible for a language to be temporarily inaccessible but to become accessible again later in life, and it might be possible to use priming to render an inaccessible language accessible again.

Finally, we support **Hagoort**'s suggestion that fMRI adaptation offers promising directions for future research that may allow us to identify more precisely the type of priming that occurs, as different linguistic representations lead to adaptation in different brain areas. This approach may be particularly appropriate for studying structures that do not involve alternations. It is also likely to be yield important findings about the neural basis of linguistic representation. It shows one way in which our proposals about the use of priming to understand linguistic representation may be extended, and therefore underlines their value in the development of the cognitive sciences of language.

Acknowledgements

This research was supported by the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 613465; the Economic and Social Research Council (grant number ESN0131151); and a Royal Society of Edinburgh/National Science Foundation of China research grant. We thank Geoff Pullum and members of the Meaning and Grammar Research Group for their comments. All views expressed are our own.

Agnew, Z K, H. van de Koot, C. McGettigan, and S K Scott. 2014. “Do Sentences with Unaccusative Verbs Involve Syntactic Movement? Evidence from Neuroimaging.” *Language, Cognition and Neuroscience* 29 (9): 1035–45. doi:10.1080/23273798.2014.887125.

Allen, Kachina, Steven Ibara, Amy Seymour, Natalia Cordova, and Matthew Botvinick. 2010. “Abstract Structural Representations of Goal-Directed Behavior.” *Psychological Science* 21 (10): 1518–24. doi:10.1177/0956797610383434.

Arai, Manabu, Roger P. G. van Gompel, and Christoph Scheepers. 2007. “Priming Ditransitive Structures in Comprehension.” *Cognitive Psychology* 54 (3): 218–50. doi:10.1016/j.cogpsych.2006.07.001.

Bencini, Giulia M.L., and Virginia V. Valian. 2008. “Abstract Sentence Representations in 3-Year-Olds: Evidence from Language Production and Comprehension.” *Journal of Memory and Language* 59 (1): 97–113. doi:10.1016/j.jml.2007.12.007.

Bernolet, Sarah, Robert J. Hartsuiker, and Martin J. Pickering. 2013. “From Language-Specific to Shared Syntactic Representations: The Influence of Second Language Proficiency on Syntactic Sharing in Bilinguals.” *Cognition* 127 (3): 287–306. doi:10.1016/j.cognition.2013.02.005.

Bernolet, Sarah, Robert J Hartsuiker, and Martin J Pickering. 2007. “Shared Syntactic Representations in Bilinguals: Evidence for the Role of Word-Order Repetition.” *Journal of Experimental Psychology. Learning, Memory, and Cognition* 33 (5): 931–49. doi:10.1037/0278-7393.33.5.931.

Berwick, R. C., and A. S. Weinberg. 1984. *The Grammatical Basis of Linguistic Performance: Language Use and Acquisition*. Cambridge Mass: MIT Press.

Bever, T., and M. Sanz. 1997. “Empty Categories Access Their Antecedents during Comprehension: Unaccusatives in Spanish.” *Linguistic Inquiry* 28: 69–91.

Bock, J.Kathryn. 1986. “Syntactic Persistence in Language Production.” *Cognitive Psychology* 18 (3): 355–87.

Bock, Kathryn. 1989. “Closed-Class Immanence in Sentence Production.” *Cognition* 31 (2): 163–86. doi:10.1016/0010-0277(89)90022-X.

Bock, Kathryn, and Zenzi M Griffin. 2000. “The Persistence of Structural Priming: Transient Activation or Implicit Learning?” *Journal of Experimental Psychology. General* 129: 177–92. doi:10.1037/0096-3445.129.2.177.

Bock, Kathryn, and Helga Loebell. 1990. “Framing Sentences.” *Cognition* 35: 1–39. doi:10.1016/0010-0277(90)90035-I.

Bock, Kathryn, Janet L Nicol, and J Cooper Cutting. 1999. “The Ties That Bind: Creating Number Agreement in Speech.” *Journal of Memory and Language* 40 (3): 330–46. doi:10.1006/jmla.1998.2616.

Bott, Lewis, and Emmanuel Chemla. 2016. “Shared and Distinct Mechanisms in Deriving Linguistic Enrichment.” *Journal of Memory and Language* 91. The Authors: 117–40. doi:10.1016/j.jml.2016.04.004.

Branigan, Holly P., and Janet F. McLean. 2016. “What Children Learn from Adults’ Utterances: An Ephemeral Lexical Boost and Persistent Syntactic Priming in Adult–child Dialogue.” *Journal of Memory and Language* 91 (March). Elsevier Inc.: 141–57. doi:10.1016/j.jml.2016.02.002.

Branigan, Holly P., Martin J. Pickering, and Alexandra A. Cleland. 2000. “Syntactic Co-

Ordination in Dialogue." *Cognition* 75 (2): 13–25. doi:10.1016/S0010-0277(99)00081-5.

Branigan, Holly P., Martin J. Pickering, and Janet F. McLean. 2005. "Priming Prepositional-Phrase Attachment during Comprehension." *Journal of Experimental Psychology: Learning Memory and Cognition* 31 (3): 468–81. doi:10.1037/0278-7393.31.3.468.

Branigan, Holly P., Martin J. Pickering, Janet F. McLean, and Andrew J. Stewart. 2006. "The Role of Local and Global Syntactic Structure in Language Production: Evidence from Syntactic Priming." *Language and Cognitive Processes*. doi:10.1080/016909600824609.

Bresnan, Joan. 2007. "Is Syntactic Knowledge Probabilistic? Experiments with the English Dative Alternation." In *Roots: Linguistics in Search of Its Evidential Base*, edited by Sam Featherston and Wolfgang Sternefeld, 75–96. Berlin: Mouton de Gruyter.

Bresnan, Joan, Anna Cueni, Tatiana Nikita, and R. H. Baayen. 2007. "Predicting the Dative Alternation." In *Cognitive Foundations of Interpretation*, 69–94.

Bunger, Ann, Anna Papafragou, and John C. Trueswell. 2013. "Event Structure Influences Language Production: Evidence from Structural Priming in Motion Event Description." *Journal of Memory and Language* 69 (3): 299–323. doi:10.1016/j.jml.2013.04.002.

Cai, Zhenguang G., Martin J. Pickering, and Holly P. Branigan. 2012. "Mapping Concepts to Syntax: Evidence from Structural Priming in Mandarin Chinese." *Journal of Memory and Language* 66 (4). Elsevier Inc.: 833–49. doi:10.1016/j.jml.2012.03.009.

Cann, Ronnie, Ruth Kempson, and Lutz Marten. 2005. *The Dynamics of Language: An Introduction*. St Louis: Academic Press.

Chang, Franklin, Kathryn Bock, and Adele E. Goldberg. 2003. “Can Thematic Roles Leave Traces of Their Places?” *Cognition* 90 (1): 29–49. doi:10.1016/S0010-0277(03)00123-9.

Cho-Reyes, S., and C. Thompson. 2012. “Structural Priming in Agrammatic Aphasia.” *Procedia - Social and Behavioral Sciences* 61: 259–61. doi:10.1016/j.sbspro.2012.10.176.

Chomsky, Noam. 1981. *Lectures on Government and Binding: The Pisa Lectures*. The Hague: Walter de Gruyter.

Cleland, Alexandra A., and Martin J. Pickering. 2006. “Do Writing and Speaking Employ the Same Syntactic Representations?” *Journal of Memory and Language* 54 (2): 185–98. doi:10.1016/j.jml.2005.10.003.

Culicover, Peter W, and Ray Jackendoff. 2005. *Simpler Syntax*. Vol. 10. Oxford: Oxford University Press. doi:10.1093/acprof.

Dabrowska, Ewa. 2010. “Naive v. Expert Intuitions: An Empirical Study of Acceptability Judgments.” *Linguistic Review* 27 (1): 1–23. doi:10.1515/tlir.2010.001.

Ferreira, F. 1994. “Choice of Passive Voice Is Affected by Verb Type and Animacy.” *Journal of Memory and Language* 33 (6): 715–36. doi:10.1006/jmla.1994.1034.

Ferreira, Victor S. 2003. “The Persistence of Optional Complementizer Production: Why Saying ‘that’ is Not Saying ‘that’ at All.” *Journal of Memory and Language*. doi:10.1016/S0749-596X(02)00523-5.

Foltz, Anouschka, Kristina Thiele, Dunja Kahsnitz, and Prisca Stenneken. 2015. “Children’s Syntactic-Priming Magnitude: Lexical Factors and Participant Characteristics.” *Journal of Child Language* 42 (4): 932–45. doi:10.1017/S0305000914000488.

Fox Tree, Jean E., and Paul J. A. Meijer. 1999. “Building Syntactic Structure in Speaking.” *Journal of Psycholinguistic Research* 28 (1): 71–92.

Garraffa, Maria, Moreno I Coco, and Holly P Branigan. 2015. “Effects of Immediate and Cumulative Syntactic Experience in Language Impairment: Evidence from Priming of Subject Relatives in Children with SLI.” *Language Learning and Development* 11: 18–40. doi:10.1080/15475441.2013.876277.

Gries, Stefan Th. 2005. “Syntactic Priming: A Corpus-Based Approach.” *Journal of Psycholinguistic Research* 34 (4): 365–99. doi:10.1007/s10936-005-6139-3.

———. 2011. “Studying Syntactic Priming in Corpora: Implications of Different Levels of Granularity.” In *Converging Evidence: Methodological and Theoretical Issues for Linguistic Research,* edited by Doris Schönefeld, 143–65. Amsterdam & Philadelphia: John Benjamins.

Gries, Stefan Th, and Gerrit Jan Kootstra. 2017. “Structural Priming within and across Languages: A Corpus-Based Perspective.” *Bilingualism: Language and Cognition* 20 (2). Cambridge University Press: 235–50. doi:DOI: 10.1017/S1366728916001085.

Hagoort, Peter. 2014. “Nodes and Networks in the Neural Architecture for Language: Broca’s Region and beyond.” *Current Opinion in Neurobiology* 28. Elsevier Ltd: 136–41. doi:10.1016/j.conb.2014.07.013.

Hagoort, Peter, and Peter Indefrey. 2014. “The Neurobiology of Language Beyond Single Words.” *Annual Review of Neuroscience* 37 (1). Annual Reviews : 347–62. doi:10.1146/annurev-neuro-071013-013847.

Hall, Matthew L, Victor S Ferreira, and Rachel I Mayberry. 2015. “Syntactic Priming in American Sign Language.” *PloS One* 10 (3). Public Library of Science: e0119611.

doi:10.1371/journal.pone.0119611.

Haskell, T. R., R. Thornton, and M. C. MacDonald. 2010. “Experience and Grammatical Agreement: Statistical Learning Shapes Number Agreement Production.” *Cognition* 114 (2): 151–64. doi:http://doi.org/10.1016/j.cognition.2009.08.017.

Healey, Patrick G T, Matthew Purver, and Christine Howes. 2014. “Divergence in Dialogue.” *PloS One* 9 (2): e98598. doi:10.1371/journal.pone.0098598.

Huang, Jian, Martin J. Pickering, Juanhua Yang, Suiping Wang, and Holly P. Branigan. 2016. “The Independence of Syntactic Processing in Mandarin: Evidence from Structural Priming.” *Journal of Memory and Language* 91: 81–98. doi:10.1016/j.jml.2016.02.005.

Hudson, Richard. 2010. *An Introduction to Word Grammar*. Cambridge: Cambridge University Press.

Ivanova, Iva, Martin J. Pickering, Janet F. McLean, Albert Costa, and Holly P. Branigan. 2012. “How Do People Produce Ungrammatical Utterances?” *Journal of Memory and Language* 67: 355–70. doi:10.1016/j.jml.2012.06.003.

Kaschak, Michael P., and Arthur M. Glenberg. 2004. “This Construction Needs Learned.” *Journal of Experimental Psychology: General* 133 (3): 450–67. doi:10.1037/0096-3445.133.3.450.

Kempen, G., and K. Harbusch. 2004. “A Corpus Study into Word Order Variation in German Subordinate Clauses: Animacy Affects Linearization Independently of Grammatical Function Assignment.” In *Multidisciplinary Approaches to Language Production*, edited by T Pechmann and C. Habel, 173–181. Berlin: Mouton de Gruyter.

Kim, Albert, and Lee Osterhout. 2005. “The Independence of Combinatory Semantic

Processing: Evidence from Event-Related Potentials." *Journal of Memory and Language* 52 (2): 205–25. doi:10.1016/j.jml.2004.10.002.

Knoeferle, Pia. 2014. "Conjunction Meaning Can Modulate Parallelism Facilitation: Eye-Tracking Evidence from German Clausal Coordination." *Journal of Memory and Language* 75 (August): 140–58. doi:10.1016/j.jml.2014.05.002.

Köhne, Judith, Martin J Pickering, and Holly P Branigan. 2014. "The Relationship between Sentence Meaning and Word Order: Evidence from Structural Priming in German." *Quarterly Journal of Experimental Psychology (2006)* 67 (2). Routledge: 304–18. doi:10.1080/17470218.2013.807855.

Konopka, Agnieszka E, and Kathryn Bock. 2009. "Lexical or Syntactic Control of Sentence Formulation? Structural Generalizations from Idiom Production." *Cognitive Psychology* 58 (1). Elsevier Inc.: 68–101. doi:10.1016/j.cogpsych.2008.05.002.

Larson, Richard K. 1988. "On the Double Object Construction." *Linguistic Inquiry* 19 (3). The MIT Press: 335–91. http://www.jstor.org/stable/25164901.

Luka, Barbara J., and Lawrence W. Barsalou. 2005. "Structural Facilitation: Mere Exposure Effects for Grammatical Acceptability as Evidence for Syntactic Priming in Comprehension." *Journal of Memory and Language* 52 (3): 444–67. doi:10.1016/j.jml.2005.01.013.

Mahowald, Kyle, Ariel James, Richard Futrell, and Edward Gibson. 2016. "A Meta-Analysis of Syntactic Priming in Language Production." *Journal of Memory and Language* 91. Elsevier Inc.: 5–27. doi:10.1016/j.jml.2016.03.009.

Malhotra, G., Martin Pickering, H. Branigan, and J.A. Bednar. 2008. "On the Persistence of Structural Priming: Mechanisms of Decay and Influence of Word-Forms." In

Proceedings of the 30th Annual Conference of the Cognitive Science Society, 657–62. http://www.psy.ed.ac.uk/people/martinp/pdf/46-persistence of structural priming2008.pdf.

Marslen-Wilson, William, Lorraine K. Tyler, Rachelle Waksler, and Lianne Older. 1994. "Morphology and Meaning in the English Mental Lexicon." *Psychological Review*. doi:10.1037/0033-295X.101.1.3.

McDonough, Kim, and Alison Mackey. 2006. "Responses to Recasts: Repetitions, Primed Production, and Linguistic Development." *Language Learning* 56 (4): 693–720. doi:10.1111/j.1467-9922.2006.00393.x.

Melinger, Alissa, and Alexandra A Cleland. 2011. "The Influence of Sentential Position on Noun Phrase Structure Priming." *Quarterly Journal of Experimental Psychology* 64 (11): 2211–35. doi:10.1080/17470218.2011.586709.

Menenti, Laura, Sarah M E Gierhan, Katrien Segaert, and Peter Hagoort. 2011. "Shared Language: Overlap and Segregation of the Neuronal Infrastructure for Speaking and Listening Revealed by Functional MRI." *Psychological Science* 22 (9): 1173–82. doi:10.1177/0956797611418347.

Messenger, K., H.P. Branigan, and J.F. McLean. 2011. "Evidence for (Shared) Abstract Structure Underlying Children's Short and Full Passives." *Cognition* 121 (2). doi:10.1016/j.cognition.2011.07.003.

Messenger, K., H.P. Branigan, J.F. McLean, and A. Sorace. 2012. "Is Young Children's Passive Syntax Semantically Constrained? Evidence from Syntactic Priming." *Journal of Memory and Language* 66 (4). doi:10.1016/j.jml.2012.03.008.

Osterhout, L, and Linda A. Mobley. 1995. "Event-Related Brain Potentials Elicited by

Failure to Agree." *Journal of Memory and Language* 34 (6). Academic Press Inc.: 739–73. doi:10.1006/jmla.1995.1033.

Pickering, M., and G. Barry. 1993. "Dependency Categorial Grammar and Coordination." *Linguistics* 31: 855–902.

Pickering, Martin J., and Holly P. Branigan. 1998. "The Representation of Verbs: Evidence from Syntactic Priming in Language Production." *Journal of Memory and Language* 39 (4). Academic Press: 633–51.

Pickering, Martin J., and Simon Garrod. n.d. "Priming and Language Change." In *The Changing English Language: Psycholinguistic Perspectives*, edited by M. Hundt, S Mollin, and S.E. Pfenninger. Cambridge: Cambridge University Press.

Pickering, Martin J., Janet F. McLean, and Holly P. Branigan. 2013. "Persistent Structural Priming and Frequency Effects during Comprehension." *Journal of Experimental Psychology: Learning, Memory, and Cognition* 39 (3): 890–97. doi:10.1037/a0029181.

Pollard, Carl, and Ivan A. Sag. 1994. *Head-Driven Phrase Structure Grammar*. Vol. 8. Chicago: University of Chicago Press.

Reitter, David, and Johanna D. Moore. 2014. "Alignment and Task Success in Spoken Dialogue." *Journal of Memory and Language* 76 (October): 29–46. doi:10.1016/j.jml.2014.05.008.

Rowland, Caroline F, Franklin Chang, Ben Ambridge, Julian M Pine, and Elena V M Lieven. 2012. "The Development of Abstract Syntax : Evidence from Structural Priming and the Lexical Boost." *Cognition* 125 (1). Elsevier B.V.: 49–63. doi:10.1016/j.cognition.2012.06.008.

Scarborough, Don L.;, Charles; Cortese, and Hollis S. Scarborough. 1977. “Frequency and Repetition Effects in Lexical Memory.” *Journal of Experimental Psychology: Human Perception and Performance* 3 (1): 1–17.

Scheepers, Christoph. 2003. “Syntactic Priming of Relative Clause Attachments: Persistence of Structural Configuration in Sentence Production.” *Cognition* 89: 179–205. doi:10.1016/S0010-0277(03)00119-7.

Schoonbaert, Sofie, Robert J. Hartsuiker, and Martin J. Pickering. 2007. “The Representation of Lexical and Syntactic Information in Bilinguals: Evidence from Syntactic Priming.” *Journal of Memory and Language* 56: 153–71. doi:10.1016/j.jml.2006.10.002.

Segaert, Katrien, Laura Menenti, Kirsten Weber, Karl Magnus Petersson, and Peter Hagoort. 2012. “Shared Syntax in Language Production and Language Comprehension-An fMRI Study.” *Cerebral Cortex* 22 (7): 1662–70.

Segaert, Katrien, Linda Wheeldon, and Peter Hagoort. 2016. “Unifying Structural Priming Effects on Syntactic Choices and Timing of Sentence Generation.” *Journal of Memory and Language* 91: 59–80. doi:10.1016/j.jml.2016.03.011.

Smith, Mark, and Linda Wheeldon. 2001. “Syntactic Priming in Spoken Sentence Production - An Online Study.” *Cognition* 78: 123–64. doi:10.1016/S0010-0277(00)00110-4.

Snyder, William. 2000. “An Experimental Investigation of Syntactic Satiation Effects.” *Linguistic Inquiry*. doi:10.1162/002438900554479.

Sprouse, Jon. 2009. “Revisiting Satiation: Evidence for an Equalization Response Strategy.” *Linguistic Inquiry* 40 (2): 329–41. doi:10.1162/ling.2009.40.2.329.

Sprouse, Jon, Matt Wagers, and Colin Phillips. 2012. “A Test of the Relation between

Working-Memory Capacity and Syntactic Island Effects." *Language* 88 (1): 82–123. doi:10.1353/lan.2012.0004.

Steedman, Mark. 2000. *The Syntactic Process*. MIT Press.

———. 2002. "Plans, Affordances, And Combinatory Grammar." *Linguistics and Philosophy* 25 (5/6). Kluwer Academic Publishers: 723–53. doi:10.1023/A:1020820000972.

Szmrecsanyi, B. 2006. *Morphosyntactic Persistence in Spoken English. A Corpus Study at the Intersection of Variationist Sociolinguistics, Psycholinguistics, and Discourse Analysis.* Berlin/New York: Mouton de Gruyter. doi:DOI: 10.1515/9783110197808.

Thothathiri, Malathi, and Jesse Snedeker. 2008. "Give and Take: Syntactic Priming during Spoken Language Comprehension." *Cognition* 108: 51–68. doi:10.1016/j.cognition.2007.12.012.

Traxler, Matthew J, Kristen M Tooley, and Martin J Pickering. 2014. "Syntactic Priming during Sentence Comprehension: Evidence for the Lexical Boost." *Journal of Experimental Psychology: Learning Memory and Cognition* 40 (4): 905–18. doi:10.1037/a0036377.

van der Cavey, Joris, and Robert J. Hartsuiker. 2016. "Is There a Domain-General Cognitive Structuring System? Evidence from Structural Priming across Music, Math, Action Descriptions, and Language." *Cognition* 146: 172–84. doi:10.1016/j.cognition.2015.09.013.

Van Gompel, Roger P.g., Martin J Pickering, Jamie Pearson, and Gunnar Jacob. 2006. "The Activation of Inappropriate Analyses in Garden-Path Sentences: Evidence from Structural Priming." *Journal of Memory and Language* 55 (3): 335–62.

doi:10.1016/j.jml.2006.06.004.

Zaenen, Annie~E. 1988. “Unaccusative Verbs in Dutch and the Syntax-Semantics Interface.” *CSLI/SRI International* 123. Stanford: 317–335.